Investigation of the influence of the spatial porous structure on heat transfer in a high-temperature heat exchanger manufactured using additive 3D printing technology

The developing technologies of additive 3D printing in metal are opening new possibilities for creating complex constructions and structures that were previously unattainable using traditional machining techniques. The project proposes the design and fabrication of a high-temperature tubular heat exchanger with a porous internal structure, which will be entirely 3D printed from aluminium, and later in the project, also from steel. The heat exchanger will serve as an absorber in a parabolic solar collector, allowing temperatures above 220°C to be achieved by concentrating the solar radiation beam. Air will be used as the working fluid in the system.

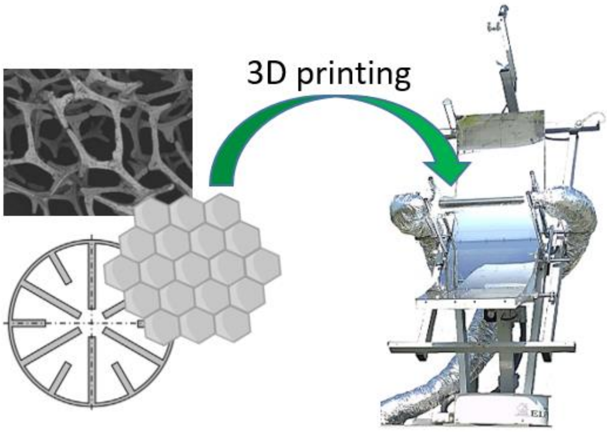

Fig. Project result: high-efficiency porous linear absorber for a high-temperature concentrating collector made on a 3D printer

Previous research results indicate a significant improvement in the thermal efficiency of the tubular heat exchanger when additional fins are used. This is particularly important in the specific heat exchange processes in solar concentrators, where only half of the exchanger is heated to high temperatures, and a common problem is the heat absorption by the working fluid. Therefore, a large part of the project tasks will be related to analysing over 100 different internal geometries of the absorber, including bionics inspired by nature, Voronoi-type foams, and various configurations of transverse and longitudinal fins. Analytical and numerical CFD modelling will be performed for the selected solutions to determine the impact of a given geometry on heat exchange and thermal-fluid processes, including pressure drops caused by flow resistance.

The nine best structures will be printed and experimentally tested to validate the models. The existing test stand with a solar concentrator will be rebuilt and equipped with new sensors, allowing for a detailed analysis of the ongoing processes as well as performing thermographic analyses of the cross-section (absorber outlet). The obtained theoretical and experimental results will serve as input for AI, which will help select three final spatial geometries optimized for selected thermal-fluid parameters. The final heat exchangers will be printed from both aluminium and steel and tested according to the previously prepared experimental plan, on a stand with a solar concentrator.

The project will be carried out with the support of scientists from the renowned research institute Plataforma Solar de Almeria in Spain, who will be involved in preparing the research plan and consulting during modelling and experimental work. The final result of the research conducted in the project will be the identification of unique geometries of linear absorbers that, thanks to their porous structure, ensure the intensification of heat exchange and thus high thermal-fluid efficiency.